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WORK PLAN FOR IN-SITU BIOREMEDIATION TREATABILITY TESTING FOR THE L.E. CARPENTER & COMPANY FACILITY WHARTON, NEW JERSEY

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SECTION 1.0

INTRODUCTION

1.1 Project Description

This Work Plan provides an overview of the proposed treatability testing for the in-situ bioremediation of contaminated groundwater and soils at the L.E. Carpenter site. The treatability investigation is being conducted to support the evaluation of treatment alternatives for groundwater and soil remediation which were presented in the Draft Feasibility Study (FS).

The Draft FS, dated 1 April 1991 and prepared by Weston Services, Inc. (WSI), identified and evaluated remedial alternatives for site remediation. In-situ Bioremediation was identified as the recommended remediation alternative. The conceptualized remediation system would include extraction of the contaminated groundwater plume, aboveground enhanced biological treatment of the extracted groundwater and addition of dissolved oxygen and nutrients prior to reintroduction of treated groundwater to the subsurface. The treatment system would most likely consist of a fixed film submerged bioreactor, utilizing either naturally occurring or specifically adapted microorganisms. The system may also include vapor phase granular activated carbon (GAC) treatment for organic constituents in the off-gas from the bioreactor and/or the equalization tank. The treatment system is expected to be converted to water phase carbon adsorption as contaminant concentrations in the extracted groundwater diminish. The treated groundwater would infiltrate via a percolation system into site soils which would allow the water to trickle through the vadose zone. A floating immiscible product layer is the primary source of contamination in this area and most of the soil contamination is present in the deeper soils near the water table. By allowing the treated, amended groundwater to trickle through the vadose zone, the potential for contaminant/moisture contact with the soil pores increases, thereby theoretically stimulating microbial degradation of contaminants sorbed to soil particles within the vadose zone.

This work plan provides a description of the preliminary treatability testing program proposed to evaluate the basic feasibility of the recommended remediation alternative. As shown in Figure 1-1, the testing involves a number of general components, including appropriate laboratory tests to evaluate the basic applicability of the technology to site contaminants and conditions. Should the testing show positive results for the bioremediation technology, further developmental testing would be proposed to evaluate the technology in more detail. Should testing show that the bioremediation option is not viable for the site, subsequent activities would be modified to evaluate the use of a GAC system as the primary means of groundwater remediation.

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FIGURE 1-1

PROPOSED TREATABILITY TESTING PROGRAM OVERVIEW

Preliminary Laboratory Testing of the Selected Remedial Technology	
Groundwater	Soils
Goal: Evaluate suitability of groundwater for treatment • Groundwater Characterization • Microbial Inhibition Test • Batch Biodegradation Studies • Treatment Parameter Optimization	Goal: Evaluate suitability of soil to flushing and enhanced biodegradation • Geotechnical Soil Characterization • Microbiological Testing • Column Flushing/Leaching Tests

Section 2 of this work plan provides a description of the general experimental design for the program, including the rationale for the proposed testing. Section 3 of this work plan provides an overview of the sampling and analytical methods to be employed during the testing.

1.2 Background

The L.E. Carpenter site is a National Priorities List (NPL) site located in Morris County, New Jersey. The site was formerly used as a magnetite mine and a forge during the 1800s. Tailings from these mines are thought to have been disposed on-site. The Replogle Steel Company formerly occupied the area along the southern bank of Washington Forge Pond. The L.E. Carpenter site was used by several textile businesses dating from the late 1800s. Around 1900, a flume was constructed to convey water for power generation from above the dam of the Washington Forge Pond to the mill race south of Building 12, the power plant. The boilers in Building 12 were coal-fired from the power plant's construction in 1925 to 1953, when the fuel was switched to No. 6 fuel oil.

L.E. Carpenter manufactured vinyl wall covering at the site from 1943 to June 1987. Between 1963 and 1970, L.E. Carpenter disposed of polyvinyl chloride sludge in a surface impoundment on the southeastern portion of the site. Other significant features of the L.E. Carpenter operation include the tank farm, nine underground storage tanks, the de-sizing process waste tanks, the former starch drying beds, and the noncontact cooling water discharge points located at the drainage feature in the northern-most corner of the site and near the 90-degree bend of the drainage ditch. Currently, portions of the site west of the railroad tracks are rented to several tenant businesses.

The primary dissolved groundwater contaminants are bis(2-ethylhexyl)phthalate (DEHP), xylene, and ethylbenzene. Most of the contaminants are located in the shallow groundwater zone. An immiscible product layer is located in some areas of the site at the water table interface, 3 to 5 feet below the ground surface. Contaminant concentrations in surface soils (less than 1 foot deep) were found to be significantly lower than in soils near the groundwater interface. Thus, the immiscible product layer appears to be the primary source of soil contamination and most of the soil contamination is present in the deeper soils.

As of May 1991, all of the primary contaminant sources have been remediated. A total of eight (8) underground storage tanks were removed in accordance with an DEPE approved tank closure plan. In addition, as of November 1990, L.E. Carpenter has recovered and approximately 5,000 gallons of immiscible product from the on-site recovery system. The remaining contamination is thought to be primarily the result of historical discharge from the UST's and soils in contact with the immiscible product.

1.3 Test Objective

The objective of this treatability study is to evaluate the in-situ bioremediation treatment process for its potential applicability for the treatment of contaminated groundwater at the L.E. Carpenter site. The potential for enhanced biodegradation and flushing of soil contaminants at the water table interface will also be evaluated. The primary focus of this initial testing will be to demonstrate basic applicability of the process to the site. Additional testing and development work may be necessary at the final remediation design stage before it can be ultimately implemented on a full-scale basis.

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SECTION 2

EXPERIMENTAL DESIGN AND PROCEDURES

2.1 Overview

The experimental design and procedures discussed in this section address each major component of the treatability testing program for the L.E. Carpenter site.

2.2 Preliminary Laboratory Testing of the Proposed Remedial Technology

The preliminary treatability testing program is intended to evaluate the basic feasibility of the proposed remedial technology as a prelude to more definitive bench scale, pilot scale, and engineering design evaluations. As such, this initial program has the following specific goals:

- Evaluate site groundwater with respect to parameters which may effect treatability or the need for potential pretreatment of the waste stream prior to organic contaminant removal.
- Screen site groundwater to evaluate the presence or absence of microbial inhibitory substances.
- Evaluate the biodegradability of contaminants in site groundwater under various conditions, and evaluate the suitability of the groundwater for biological treatment.
- Evaluate site soils with respect to physical parameters which may determine the effectiveness of in-situ flushing.
- Identify the basic types of soil microorganisms in east site soils, the anticipated location of treated groundwater discharge.
- Evaluate site soils with respect to potential for supporting contaminant reduction via in-situ flushing/leaching, plus recovery of groundwater.

The following subsections discuss testing to be conducted in pursuit of these goals.

2.2.1 Groundwater Testing

2.2.1.1 Groundwater Characterization

In conjunction with biodegradation testing, groundwater samples from the site will be characterized with respect to parameters which may effect treatability or the need for potential pretreatment of the waste stream prior to organics removal. Tests to be conducted include:

- Total Solids, Total Suspended Solids, Total Dissolved Solids
- Conductivity
- Acidity/Alkalinity (titration curves)
- pH
- Nitrogen (TKN and Ammonia)
- Total Phosphorous
- BOD_5 and COD
- Total Metals
- VOCs and BNs
- Total and Dissolved Solids

Data developed during this characterization will be used to finalize the protocol for the microbial inhibition and batch biodegradation testing.

2.2.1.2 Microbial Inhibition Test

The acute microbial inhibition test procedure was developed by WESTON as an initial screening study to determine the presence or absence of inhibitory substances in waste streams. The study is a modification of the five-day biochemical oxygen demand (BOD_5) test. As such, the removal of dissolved oxygen from a closed aquatic test system is used as the indicator of microbial inhibition. The method involves incubating a series of BOD bottles containing various dilutions of waste (i.e., test compounds) and a microbial seed culture (acclimated or unacclimated).

A series of 300 ml BOD bottles are filled with a mixture of microbial inoculum, dilution water, a known amount of a readily degradable primary substrate (d-glucose), and varying concentrations of the test substance. The concentration of dissolved oxygen (DO) is determined in each bottle, and the bottles are subsequently sealed and incubated at 20°C for three days.

After incubation for three days, the concentration of DO is determined in each bottle. A graph of the data is drawn with DO (mg/l) as the independent variable (y axis) and log test substance concentration (in appropriate units) as the dependent variable. If the test substance is microbially inhibitory, a decrease in the amount of oxygen utilized at higher test concentrations will be noted.

2.2.1.3 Batch Biodegradation Studies

The biodegradability of contaminants in site groundwater will be evaluated under several conditions, using a batch (shaker flask) study. Portions of contaminated groundwater will be supplemented with a nutrient mixture to facilitate degradation. Tests will be conducted

both with and without microbial seed. Potential sources of microbial seed include site soils (depending upon results of microbial characterization discussed in Section 2.2.2.2) and biomass from industrial wastewater treatment plants. After introduction of nutrients and seed (where appropriate) flasks will be loosely stoppered (e.g., glass wool) and agitated on laboratory shaker tables to provide aerobic conditions. Contaminant profiles will be assessed over time.

The concentration of contaminated groundwater to be utilized for the test is important. Use of groundwater with too low a contaminant load will be insufficient to sustain microbial activity, while groundwater which is heavily contaminated may inhibit microbial activity. A groundwater sample will be obtained from the most contaminated well on site. Sampling will exclude the miscible layer, since the layer will be removed by skimmers during full scale remediation. Based upon the results of the microbial inhibition test, other baseline groundwater characterization tests and the technical judgement of treatability lab personnel, a raw groundwater sample obtained from the field may be diluted to an appropriate concentration, as required, for use in the batch study.

A testing program involving up to five sets of shaker flasks is proposed. Each flask set would consist of three individual flasks, making a total of up to fifteen flasks for the study. The proposed sets include the following:

- Control - These flasks will contain groundwater which has been sterilized or chemically poisoned.
- Groundwater/Natural Bacteria - These flasks will contain raw groundwater with its naturally associated bacteria.
- Unacclimated Seed - These flasks will contain raw groundwater with unacclimated activated sludge microbial seed from a waste water treatment plant.
- Acclimated Seed - These flasks will contain raw groundwater with activated sludge microbial seed which has been acclimated to the site groundwater via previous contact.
- Site Soil Seed - Should the microbial testing described in Section 2.2.2.2 show that sufficient amounts of naturally occurring bacteria are found in site soils, these flasks will contain raw groundwater and site soil.

During the test period, anticipated to last eight weeks, test conditions such as temperature, pH, and nutrient supply will be carefully controlled to maintain all flask sets under the same conditions. Sampling of the flasks will occur at the two, four, and eight week marks during the study. At these intervals, flasks from each set will be analyzed for VOCs and BNs. Throughout the study, flasks will also be routinely tested for temperature, pH, and dissolved oxygen. COD and/or TOC will be monitored on a more frequent basis during the study.

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2.2.2 Soils Testing

2.2.2.1 Geotechnical Soil Characterization

Soil samples collected from the site will be characterized with respect to parameters which may determine the effectiveness of in-situ soil flushing. Soils to be characterized will be collected from several locations and across multiple depth intervals within the area of anticipated treated groundwater discharge in order to assess the range of characteristics which may be encountered. Specific tests to be conducted will include:

- Particle Size Distribution
- Moisture Content
- Ash and Organic Carbon Content
- Liquid and Plastic Limits
- Porosity (Density and Specific Gravity)
- Hydraulic Conductivity (Permeability)
- Field Density

2.2.2.2 Microbial Enumeration Testing

The indigenous microbial population for site soils will be evaluated in order to assess whether sufficient indigenous microbial activity may exist to support enhanced biodegradation of soil contaminants. The testing conducted under this initial evaluation will consist of microbial enumeration via the standard plate count procedure. As detailed in the draft FS (section 6.2.4.1), the literature cites several studies demonstrating the effectiveness of common soil microbes in degrading DEHP. Site specific microbes will be identified via the "Heterotrophic Plate Count, Pour Plate Method" (Method 907A, Standard Methods 16th Edition), or other accepted literature method.

2.2.2.3 Column Flushing/Leaching Tests

Two soil column flushing/leaching tests will be conducted to determine whether soils are amenable to flushing and to evaluate the potential removal of contaminants from site soils by flushing. For each such test, site soils will be packed into laboratory leaching columns to values approximating field density and subjected to constant head flushing with potable tap water. The pH of the tap water will be adjusted, if necessary, to match that of the site groundwater.

Soil samples for this testing will be collected either as soil cores or by excavation at depth intervals (i.e., 2 ft. sections) and packed into columns in the same order to approximate the existing contaminant profile at depth. The two column test will be conducted using soils representing the most favorable and least favorable potential physical soil characteristics,

as determined in previous geotechnical characterization testing. Contaminant levels in each soil column will be similar, if possible.

The test apparatus for column testing will be similar to that shown in Figure 2-1. Water samples will be taken from the column inlet and outlet, and contaminant concentrations evaluated over time. At the conclusion of each test, soil samples will be taken from the columns at depth intervals for comparison of contaminant profiles to pre-testing conditions.

An attempt will be made to simulate a given time period under anticipated full scale remediation operating conditions. Estimates will be made for total anticipated rate of treated effluent discharge, total soil surface area to be utilized for treated groundwater recharge and length of remediation system operation. These estimated values will be used to calculate a hypothesized loading rate for full scale soil flushing which can then be simulated by the column flushing test. This information can be used to create an accelerated study, simulating 10 years of full scale discharge operation in a two month period. If this accelerated study goal cannot be met, the study will still be terminated after two months, with an estimate made as to the simulated full scale operating time represented by the study.

A schematic of the column leach test apparatus is presented in Figure 2-1. A four inch diameter by four foot long heavy wall glass column is used to contain an approximately three foot soil column sample. A porous ceramic plate located at the bottom of the soil column collects the leachate discharging the soil column. A porous ceramic plate located on top the soil column provides a uniform distribution of water over the entire cross-section of the soil column. Teflon/PVC end caps are clamped to the top and bottom of the glass column using all-thread rods and nuts. Teflon and Viton o-rings seal the end caps to the glass column. Water is applied at the top of the soil column which is mounted vertically on a wooden rack. The water infiltrates downward through the soil column and discharges as leachate from the bottom.

A volumetrically graduated two gallon plexiglass reservoir is used to contain, deliver and meter the water under pressure to the soil column. Nitrogen gas is used to pressurize the reservoir. The water reservoir is refilled as required using vacuum to draw the stock water from a 55-gallon polyethylene drum.

The leachate discharging the soil column is collected in a four liter glass beaker, two liter glass buret, or a 100 milliliter glass buret depending on the leachate sample type and quantity being collected. Note that the 100 ml buret is used to grab the volatile organic sample and is equipped with a vapor trap to minimize the loss of volatiles during collection. Valves and tubing used to convey and route the permeant or leachate are constructed of stainless steel and Teflon materials.

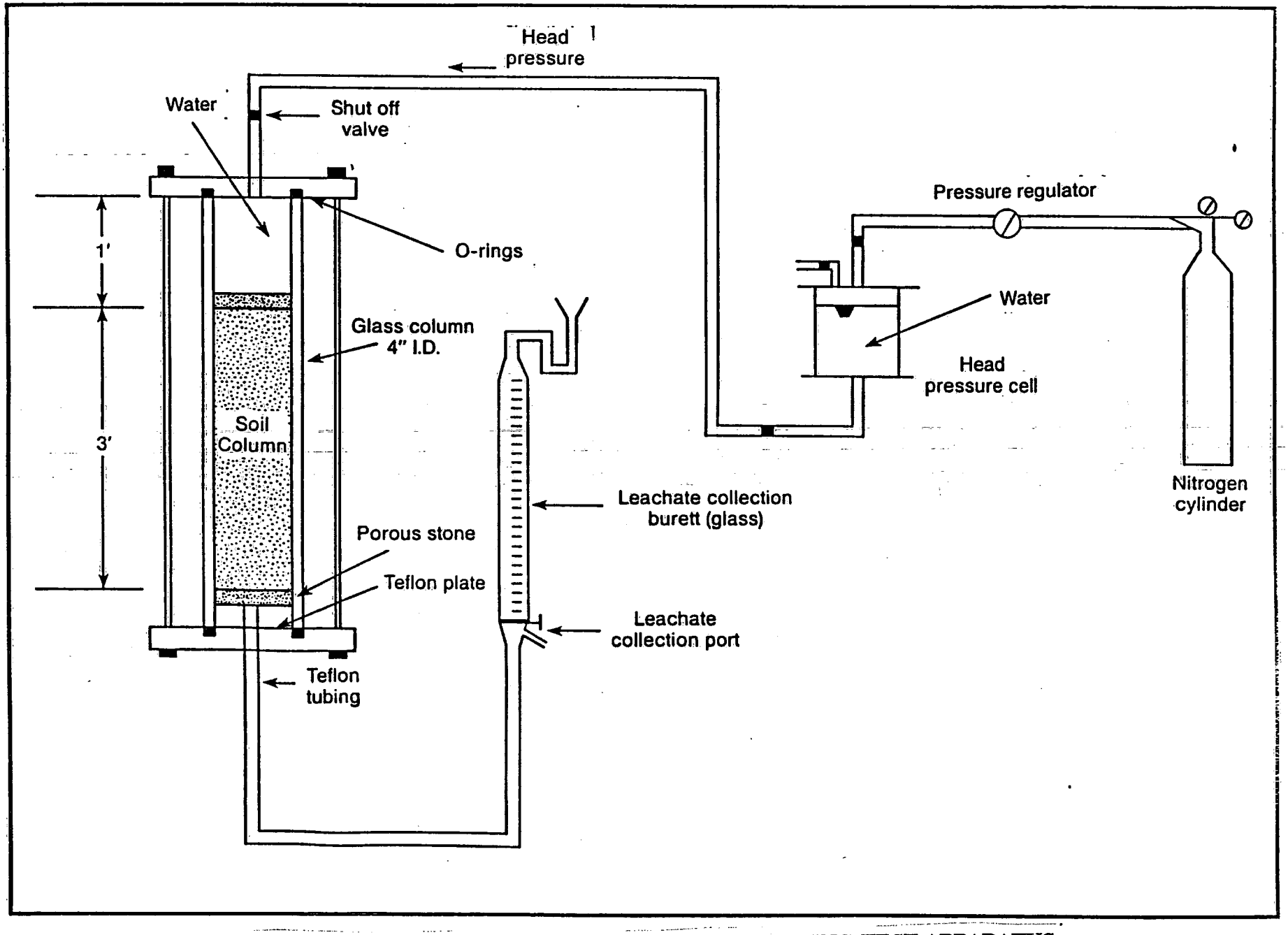

FIGURE 2-1 SCHEMATIC OF THE COLUMN LEACHING TEST APPARATUS

Once the test conditions and test parameters are defined for each soil sample, the test apparatus will be assembled and leak checked. Soil samples will be removed from the storage containers and compacted into the flask columns at the target dry density. The bottom end plate and o-ring will be attached to the bottom of the glass column and then a porous ceramic disc will be placed on top of the bottom end plate. The soil will be compacted in three inch lifts using a 2.5 kilogram cylindrical weight dropped from a constant height of 12 inches. The soil density of each lift will be controlled by varying the soil weight and number of drops applied by the compaction weight. The soil density of each lift will be monitored by measuring the incremental soil weight and volume gain with a pan balance and measuring tape. After the soil column compaction procedure is completed, the total weight, height and volume of the soil column will be recorded and used to calculate the average soil density and porosity.

During the soil compaction procedure, grab samples of soil representing each lift will be combined to form composite samples representing the total soil column. The composite sample will be mixed and split into portions for the physical and chemical test parameters described in Section 3, except for the volatile organic analysis. Grab samples for volatiles organic analysis will be collected once at the midpoint of the compaction procedure.

The top end plate and o-ring will be attached to the top of the glass column and the all-thread rods securely tightened to seal the top and bottom end plates. The column inlet and outlet valves will then be closed and the column will be leak-checked at a pressure of 40 pounds per square inch (psi). If any leaks are detected, the problem will be corrected before continuing. The water supply line will then be attached to the top end plate of the soil column and the leachate collection line will be attached to the bottom end plate.

The column leach test will be started by applying water to the top of the soil column and allowing the permeant to infiltrate through the soil at a natural rate without using applied pressure. As the leachate discharges from the soil column, total cumulative volumes, pH, COD and specific conductance of the leachate will be measured and recorded. If required, a pressure will be applied to the soil column to accelerate the permeation rate. However, the maximum test permeation rate will not be allowed to exceed the natural permeability of the soil by one order of magnitude.

Leachate samples will be collected at the beginning, mid point, and completion of the column study to be analyzed for VOCs and BNs. The laboratory will monitor pH, specific conductance, and COD frequently throughout the testing. The leachate will be collected in one liter beakers, combined and mixed before splitting into aliquots for the chemical analysis. Grab samples for volatile organic analysis will be collected directly from the column at the midpoint of the sample collection period using the 100 ml buret and vapor trap.

The permeability of the soil column will be measured at the beginning, the midpoint, and at the end of the study just before column dismantling. Permeability will be measured directly in the soil column using tap water as the fluid.

The column study will be terminated after the equivalent 10-year leachate sample is collected, or 60 test days have passed. After the final permeability measurement is performed and the leachate discharge has stopped, each soil column height will be measured. The columns will then be dismantled and the soil recovered and weighed. Grab samples of the final soil will be collected for analysis as described in Section 3. Samples will be obtained in the same numbers and column locations as carried out at the beginning of the study.

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SECTION 3

SAMPLING AND ANALYSIS

3.1 Field Sampling

During the course of this testing program, field sampling will take place at the site to generate soil and groundwater samples. Groundwater sampling will be carried out to provide suitable sample volume for initial characterization sampling and subsequent individual test protocols. Monitoring wells will be sampled utilizing approved DEPE protocols as outlined and described in prior RI/FS sampling work plans and quality assurance plans for the L.E. Carpenter site. If appropriate, bulk groundwater samples will be obtained by pumping directly into 5 gallon (or larger) containers. Soil sampling will be carried out to provide suitable sample volume for initial characterization sampling and subsequent individual test protocols. Soil will also be sampled using approved DEPE protocols as described in previous site sampling plans. Chain of custody documentation will be used to ship all samples from the field to the testing laboratory.

3.2 Treatability Testing Parameters and Methods

The chemical and physical analysis to be performed on water and soil samples prior, during, and after individual treatability tests are presented in Tables 3-1 and 3-2. The test methods used for the chemical and physical analysis are also referenced in these tables.

3.3 QA/QC and Data Management

Field and laboratory sampling procedures will comply with all QA/QC protocols established under past RI/FS submittals. Treatability laboratory activities associated with all tests will be documented. Bound notebooks will be used to record raw data and observations in the laboratory. Data collection sheets will also be used to record information during some of the tests. Chain-of-custody documentation will be used to ship samples to the various testing laboratories which may be utilized.

Data developed during the treatability study will be summarized in graphical and tabular forms to aid in the interpretation of results. Computer-based spreadsheets (Lotus 1-2-3 and/or Microsoft Excel) will be employed for data summary.

3.4 Residuals Management

All bulk samples and testing residuals will be stored in the shipping containers and placed in designated curbed areas within the treatability laboratory. These curbed areas will have

sufficient capacity to contain the volume of the largest sample container, and will be impervious to spills and leaks.

At the completion of the treatability study, all residuals will be properly containerized in accordance with applicable DOT regulations and transported back to the L.E. Carpenter site. If the residuals are determined to be subject to RCRA regulations, the hauler will be required to have an EPA identification number and RCRA manifesting procedures will be followed.

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TABLE 3-1

SUMMARY OF WATER SAMPLE ANALYTICAL PARAMETERS AND TEST METHODS

Analytical Parameters	Test Method Reference
pH	USEPA-9040
Specific Conductance	USEPA-9050
Total Solids	MCAWW 160.3
Total Suspended Solids	MCAWW 160.1
Total Dissolved Solids	MCAWW 160.2
Acidity/Alkalinity	MCAWW 305.1/310.1
Nitrogen (TKN and Ammonia)	MCAWW 351.4/350.3
Total Phosphorous	MCAWW 365.2
BODs	MCAWW 405.1
COD	MCAWW 410.2/410.4
Dissolved Oxygen	MCAWW 360.1
VO+10	USEPA 624
BN+10	USEPA 625
Total Metals	USEPA 200 Series

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TABLE 3-2

SUMMARY OF SOIL SAMPLE ANALYTICAL PARAMETERS AND TEST METHODS

Analytical Parameters	Test Method Reference
VO+10	USEPA 8240
BN+10	USEPA 8270
Soil pH (lab method)	ASTM D2976-71
Bulk Density of Undisturbed Soil	ASTM D2937-83
Bulk Density (sand cone method)	ASTM D1556-82
Hydraulic Conductivity - Flexi Wall	USEPA 9100
Total Organic Carbon	USEPA 9060
Moisture, Ash, and Organic Content	ASTM D2974-87
Soil Moisture Content	ASTM D2216-80
Particle Size Distribution	ASTM D 422-63
Specific Gravity - Pycnometer	ASTM D 854-83
Liquid and Plastic Limits	ASTM D4318-84
Porosity (bulk density and specific gravity)	Calculated
Unit Weight and Porosity	ACE Appendix II-2
Falling Head Permeability	ACE Appendix VII-13

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SECTION 4

DATA ANALYSIS AND REPORTING

The experimental data will be analyzed to determine the effectiveness of the in-situ biodegradation process in treating the L.E. Carpenter site groundwater and water table interface soils. The treatability and analytical data will be summarized in tabular and graphical form for ease of evaluation. The primary focus of the data analysis will be to evaluate the destruction of base neutral and volatile compounds, specifically DEHP, xylene and ethylbenzene.

Results of the testing program will be summarized to characterize the untreated groundwater, treated groundwater, and leached soil to determine contaminant removal effectiveness under the various test conditions.

The results of each phase of the treatability study will be used to assist in the evaluation of the in-situ biodegradation process for groundwater and soil remediation in the FS. In addition, a report summarizing the findings of the treatability study will be prepared at the conclusion of the testing program. This document will discuss the effectiveness of the process for the test conditions evaluated. The report will summarize the experimental procedures, analytical results, observations, and recommendations for further testing and development, working toward full-scale implementation. An outline for a typical treatability study report is presented in Table 4-1.

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TABLE 4-1

OUTLINE FOR TREATABILITY TESTING REPORT

1. Introduction

   1.1 Site description
   1.2 Wastestream description
   1.3 Remedial technology description

2. Treatability Study Approach

   2.1 Test objectives
   2.2 Experimental design and procedures
   2.3 Equipment and materials
   2.4 Sampling and analysis
   2.5 Data management
   2.6 Deviations from the work plan

3. Results and Discussions

   3.1 Data analysis and interpretation
   3.2 Quality assurance/quality control

4. Conclusions

   4.1 Conclusions
   4.2 Recommendations

5. References

   Appendices

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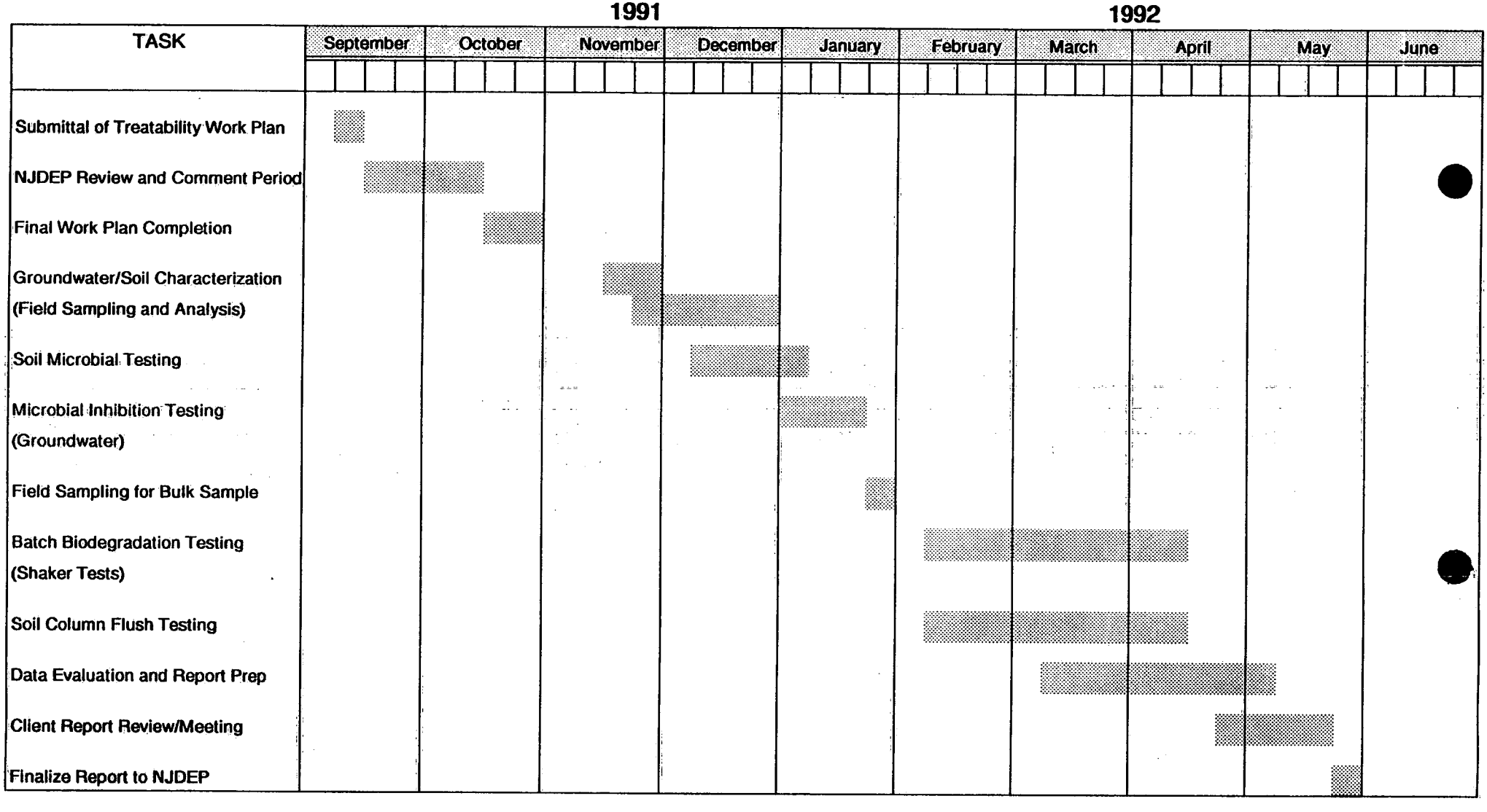
SECTION 5

SCHEDULE

A proposed schedule for the completion of each phase of the treatability study is presented in Figure 5-1. It is anticipated that the treatability testing, data analysis and reporting will be completed approximately 20 weeks after the collection and preparation of the initial groundwater and soil samples. The schedule includes estimated periods for DEPE and client review of documents and reports.

FIGURE 5–1
SCHEDULE OF TREATABILITY TESTING ACTIVITIES
L.E. CARPENTER SITE



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